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Scientific Editors

Aquatic Ecology of the Mondego River Basin
Global Importance of Local Experience

Coimbra • Imprensa da Universidade

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CRAYFISH *Procambarus clarkii* (GIRARD) IN THE LOWER MONDEGO RIVER VALLEY

Abstract

Crayfish *Procambarus clarkii* populations in the Lower Mondego River valley, were studied. The main recruitment period occurs from the second half of October to the end of November, but juveniles are found throughout the year. Average growth rate is 1.16 mm of total length per week. Production was estimated at 27.22 $g.m^{-2}$ per year, average biomass 5.4 $g.m^{-2}$ and the $P/\overline{B}$ ratio 5.03. Females outnumber males throughout the year. Reproductively active (Form I) males are abundant from May to October. Fulton's condition factor was determined for individual crayfish. Condition is dependent on sex and reproductive state, but the seasonal pattern of variation is similar for females, for all males, for reproductive males and for non-reproductive males (Form II). From December to May there is a gradual decrease in condition, ending as a steep decrease. This may be explained by a mass molting to reproductive forms. A post-reproductive decrease in condition is observed in September and October. Our data corroborate the idea that there is a relation between male condition and reproductive activity.

Introduction

The introduction of alien freshwater crayfishes in new habitats, mainly as food value, has been practiced since 1746 (Hobbs et al. 1989), and the case of *Procambarus clarkii* (Girard), a species from northeastern Mexico and the southern U.S.A., is undoubtedly a good example to illustrate the problems arising from an uncontrolled introduction of alien species (Holdich 1988). In general, this species revealed a high adaptive capacity to new available habitats, showing good tolerance to a wide range of environmental conditions (Hobbs et al. 1989). A high growth rate (Huner 1978) associated with a successful reproductive strategy is responsible for the development

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of extremely large populations, which can have a severe negative impact on agriculture areas in wetlands (e. g. rice) (Ocete and Gallego 1985). To prevent damage to rice production, farmers have repeatedly tried to eradicate crayfish populations by means of xenobiotic chemicals. Such methods proved to be ineffective and had a devastating impact on useful species (Velez 1980, Roqueplo and Hureaux 1989). In any case, once introduced into favourable habitats, *Procambarus clarkii* is rather difficult to eliminate (Holdich 1988).

The reproductive period of *Procambarus clarkii* is dependent on both environmental (e. g. climate) and endogenous physiological factors (Sommer 1984), and therefore, due to the combined effects of these factors, it may change after the species is introduced into different regions. These geographical variations are apparently a function of the hydrological cycle and temperature. For instance, a short arid period interchanging with a prolonged rainy season will increase the active period of the species, causing the development of dense populations with high growth rates, while the opposite situation will decrease the reproductive period. Nevertheless, alternating rainy and dry seasons do not fit precisely with reproductive and sexually inactive periods (Sommer 1984). On the other hand, the influence of water temperature is obvious and, at decreasing latitudes, *Procambarus clarkii* populations tend to change from univoltin to multivoltin life cycles (Huner 1981).

The growth process of *Procambarus clarkii* (Girard 1852) leads mostly to an increase in size, while sexual maturation causes allometric modifications (Romaire et al. 1977, Huner et al. 1988, Correia 1990). These morphological changes coexist with internal changes, which may be helpful to assess the condition of the population. The hepatopancreas is the main energy storage organ in crayfish (Armitage et al. 1972) and energy, moisture content, and the weight of this organ change during crayfish biological cycles (Armitage et al. 1972, Huner et al. 1985, Lahti 1988, Huner 1995, Viikinkoski et al. 1995). Thus, hepatopancreas analysis may be useful to assess crayfish condition, but alternative processes include measures of relative muscle weight and condition indices. These indices provide no information on the state of internal organs or body composition and can also be biased by the molt stage (Lindqvist and Lahti 1983, Musgrove and Geddes 1995). Nevertheless, the main advantages of a condition factor are its simplicity, and the fact that no animals are sacrificed during the process. The effects of season, sex or reproductive state can thus be identified with a small effort. Moreover, the possibility of the use of a condition factor by crayfish farmers should not be excluded. It may provide them a simple tool to diagnose crayfish condition.

The purpose of this synthesis of results included in the publications Anastácio 1993 and Anastácio et al. 1995 is to describe and understand the bioecology of *P. clarkii* populations in the lower Mondego river valley. This type of data will be useful for the management of crayfish populations.

Materials and methods

Study sites:

Three sampling sites were chosen in typical freshwater habitats for crayfish, a rice field, a swamp drainage channel and an agriculture drainage channel, respectively (Fig 1). The rice field was subjected to manipulation of water level and sampling was not possible during a considerable part of the year due to very low water levels. Water was always present in the swamp drainage channel although levels varied throughout the year. Reeds *(Phragmites australis)* were quite abundant on the banks. In the agriculture drainage channel, located in the perimeter of an agricultural area, there was a slight water flow. As a result this channel was similar to a lotic system.

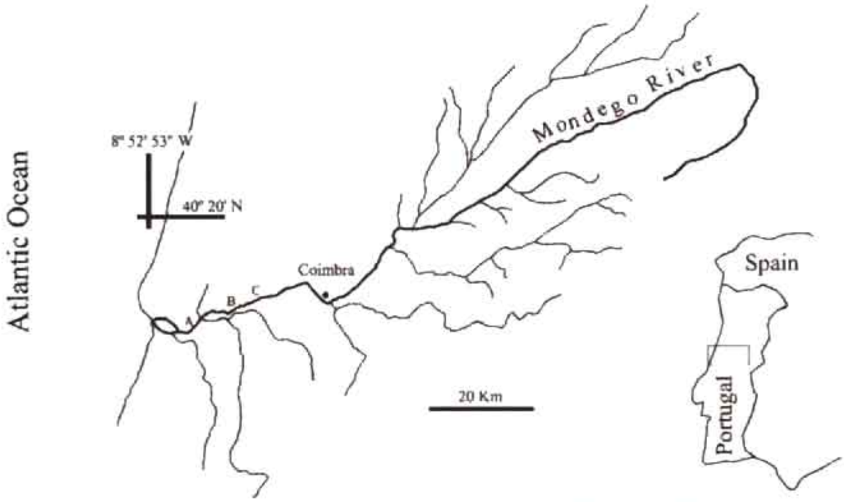

Fig. 1. Location of the sampling areas on the Lower Mondego river valley. A. rice field; B. swamp drainage chanel; C. agriculture drainage chanel.

Sampling

There were three sampling programs, and the first was carried out in all three sampling sites from October 1991 to December 1992. A fortnightly periodicity was used during the most important recruitment period and a monthly periodicity whenever recruitment was negligible. Crayfish were collected with a 1mm-mesh handnet, samples being taken from areas delimited with nets. The sampled areas corresponded to 9 m^2 in the rice field and ranged from 6 to 12 m^2 in the other two sites. In all cases sampling was carried out until no more crayfish could be caught. At each site three replicates were taken randomly using this technique. For each date and at each sampling site, temperature, dissolved oxygen (percentage of saturation) and pH were measured.

The second sampling program was carried out in the agriculture drainage channel and covered the period from June 1992 to February 1993, corresponding to one reproduction and recruitment period. Twenty-five baited Swedish type traps (20 mm mesh) were set overnight on a fortnightly basis and checked in the morning. The traps were spaced 5 m apart and baited with sardines (*Sardina pilchardus* Walbaum, 1792). Crayfish were sexed, weighed and post orbital carapace length (POCL) was measured. All crayfish were released.

The third sampling program was also carried out in the agriculture drainage channel and covered the period from May 1993 to September 1994. Due to the low number of adult crayfish obtained in the 2nd sampling program the sampling strategy was modified. Samples were collected on a monthly basis and traps were set for 3 consecutive nights and checked every morning. The same procedures as those of the previous sampling program were followed but in addition the reproductive state of males was determined. Form I males (reproductive) were identified based on the presence of copulatory hooks (Suko 1953, Taketomi et al. 1990).

Laboratory procedures (first sampling program)

Samples obtained in the first sampling period were preserved in neutralised 4% formalin and organisms were separated in the laboratory after washing with water.

Postorbital carapace length (POCL), dry weight and wet weight were determined for each animal. Crayfish smaller than 1cm (POCL) were measured using a dissecting microscope with a calibrated micrometer. The other animals were measured with a vernier caliper. Measurements were made to the nearest 0.005cm and 0.015cm, respectively. POCL proved to be better correlated with total length than full carapace length (CL). In order to compare our results with other works, which often use CL, the following regression model can be used to convert POCL into full carapace length (CL): CL = 0.149355+1.20916 POCL ($n=941$; $r^2=0.943624$), (Adão 1991)

Wet weight was determined following the Ulomski method, described by Winberg (1971) and the dry weight was determined after drying in an oven at 60°C for 7 days. Ash free dry weight was determined after reducing dried crayfish to powder, which was dried again, weighed, burned in a muffle furnace at 450°C for 9 hours and weighed again. Weight determinations were carried out with a 10^{-5}g precision.

Animals were sexed by the presence (in males) or absence (in females) of developed gonopodia, which was usually applicable for individuals larger than 1cm (POCL). Form I males (reproductive) were identified based on the presence of copulatory hooks (Taketomi et al. 1990) and on the hardness and colour of the gonopodia.

Growth and mortality rates (first sampling program)

Growth and mortality rates were estimated by tracking recognisable cohorts along size-frequency distributions (2 mm length classes) at successive sample dates. Size-frequency analysis was executed by using the probability paper method (Harding 1949) as performed by Cassie (1954, 1963). Reliability was tested employing both X^2 and G tests ($P<0.05$) (Fisher 1950, Sokal and Rohlf 1981). Computations were performed using ANAMOD software (Nogueira 1992). Normally, growth rates are not constant through the year, therefore, seasonal variations were taken into consideration using a model proposed by Gaschütz et al. (1980, see Anastácio and Marques 1995 for details).

Production and Average Biomass estimates (first sampling program)

Production was estimated using Allen curves (Peer 1970, Wildish and Peer 1981). The production estimate for each cohort was achieved by determining the average wet weight of the animals of a given cohort. Density was then plotted against time and the same was done with regard to the weight. A new data set was then obtained by the adjustment of curves to both plots. The final step was the plot of density against average wet weight for each sampling date, where cohort production was given by the integral of the curve adjusted to this plot.

The average biomass was determined by the ratio of the biomass integral within a given time interval and the time interval (Allen 1971). The biomass of a cohort in a given time is the product of individual average weight and the density of the cohort. Total biomass was calculated by the sum of the biomasses of all cohorts tracked in a given instant. Average biomass was determined after fitting a 4th order polynomial function to data.

Condition factor (second and third sampling programs)

For each crayfish captured Fulton's condition factor (Ricker 1975) was calculated by the formula: $Weight/Length^3$. Wet weight and POCL were used in this formula. Average condition factors were calculated for each sampling date.

Data were tested for correlations of POCL vs. condition. The analysis was performed using individual crayfish values, and also daily averages. Correlation was also determined for the relative abundance of Form I males vs. the average condition factor of the males. Pearson's product-moment correlation coefficient (Zar 1984) was used for all the correlations. A one-way ANOVA (Zar 1984) was performed with data from the third sampling program. The objective was to determine if there were differences in the average condition of the following population sub-groups: females, Form I males, Form II males, and all males.

Results

Physicochemical data

With the exception of the temperature, a pattern of variation could not be recognised throughout the year. The main difference between temperatures at the three sites was the higher annual variation at the rice field (R.F.). Temperatures ranged from 5°C to over 30°C. Median oxygen saturation were higher and more variable at the agriculture drainage channel (A.D.C.), usually ranging from 40% to 180%. The highest values of pH were found at A.D.C. with a median value of approximately 7.5. pH values ranged between 6.3 and 8.5. In general terms physicochemical characteristics were not very different at the three sampling sites.

1st sampling program

Population structure

Seven cohorts were tracked for variable periods of time (Fig. 2). Cohorts 1, 2 and 3 were recognised on 26 October, cohort 4 was identified on 18 January, cohort 5 on 19 August, cohort 6 on 25 September and cohort 7 on 6 November. Cohort 3 exhibited the longest recruitment period, which lasted for approximately one month. Cohorts recognised in August and September did not consist of newly born individuals, and therefore recruitment must have taken place previously, although it was not detected. Recruitment dates of these two cohorts were estimated after knowing the approximate growth rate.

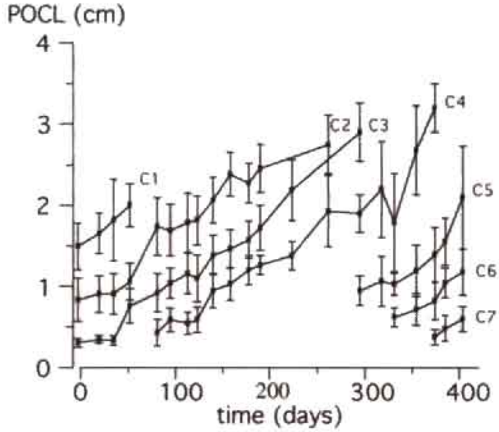

Fig. 2. Increase on the average POCL (Post Orbital Carapace Length) of each cohort throughout the study period. Standard deviations are also represented. C1, C2... C7 are the cohorts 1 to 7.

Recruitment was higher from the second half of October to the beginning of December. Other recruitment periods were also noticed in May and August. Animals with a POCL smaller than 1cm, which were considered to be juveniles, could be found throughout the year, except from May to July.

The average sex ratio was 0.24, ranging from 0.143 to 0.5 and it was not possible to recognise any regular pattern of variation. A total of 40 adult males was recognisable from samples, the smallest one (a form I male) 2.52 cm of POCL. Of these, 26 (67%) were form I. Only one ovigerous female was observed and due to the small number of adults collected it was difficult to determine the type of variations in reproductive stage or condition that occurred throughout the year.

Size-weight relationships

Taking into consideration animals equal or larger than 0.25 cm POCL, POCL-dry weight relationships may be expressed by the following regression model: $Y=0.080250916x^{3.07156}$ ($r^2=0.939$; $n=1278$; $P<0.001$). For animals smaller than 0.25 cm POCL no significant correlation was found ($P>0.05$; $r^2=0.0006$; $n=122$), and therefore a median value of 0.00096g was considered for their individual weight.

Also, POCL and wet weight were found to be significantly correlated according to the following regression model: $Y=0.49675243x^{2.879349}$ ($r^2=0.922$; $n=758$; $P<0.001$). In this case only animals larger than 0.4cm POCL were considered. The correlation for animals smaller than 0.4cm was not significant ($P>0.05$; $r^2=0.0077$; $n=106$) and, like in the previous case, an average individual weight of 0.0012g was considered.

Growth

Size-frequency analysis provided the average POCL size of each cohort and the correspondent standard deviation at each sampling date (Fig. 2). Seven cohorts were tracked for periods variable from 30 (cohort 7) to 237 days (cohort 4). Data on each cohort were used to adjust growth curves, and the fit was carefully compared based on r^2 values for a given number of data points. The curve with the best fit was then selected.

Cohort 3 provided the most consistent data on field growth rates, ($r^2=0.98757$ for 12 data points). The first two points were not taken into consideration since they seemed not to make sense. Therefore data on cohort 3 were merged with some data on cohort 2 in order to calibrate a growth model for winter cohorts of *Procambarus clarkii* in the Lower Mondego River valley.

The estimated Gauschutz growth model parameters are as follows: $L\infty = 5.6$, $t_0 = -0.077838123$, $K = 0.68220933$, $t_s = 0.57738118$, $C = 0.44322345$ and $D = 1$. The value of "D" was assumed to be 1, since information on metabolic rate of this species was not obtained. From the model, average growth rate was 1.16mm per week for total length, corresponding to 0.61mm per week for carapace length and to 0.5mm per week for postorbital carapace length.

Density and mortality

Size frequency analysis also allowed an estimate of the density of each cohort at each sampling date, although some sampling constraints related to the capture technique might have caused some bias on the data. Actually, newly released individuals and especially adults have most likely been underestimated. This problem was partially solved by the adjustment of a negative exponential curve to the densities of the cohorts: $y=a.10^{-bx}$ where x and y are time in days and density ($ind.m^{-2}$), respectively and "a" and "b" are parameters to be determined. All the curves with more than three data points presented a good fit ($P<0.05$). Cohort 7 was adjusted to a curve with a value of "b" equal to the average of that parameter for all the other curves.

For these calculations, mortality (m) was assumed to be constant for each cohort, and can be determined from:

$$m = \left|\frac{(a \cdot 10^{-bx})'}{a \cdot 10^{-bx}}\right| = \left|\frac{-b \cdot \ln \cdot a \cdot 10^{-bx}}{a \cdot 10^{-bx}}\right| = |-b \cdot \ln 10|$$

where "m" is the daily mortality rate, "a" and "b" are parameters of the density equation for each cohort, and "x" is the time in days.

Cohort production estimates

The Allen curve method as originally described takes into account a limited number of data points. However, a previous determination of equations for density and wet weight, made possible the use of more data points. The method used to estimate production was based on the plot of the daily relationship between the density and the average wet weight of each cohort. A curve of the type $y=a*10^{-bx}$ was then adjusted to data points, the production being given by the integral of this function. Total production within a period of 407 days was determined by summing the different cohort production estimates. Production was estimated at 27.219 $g.m^{-2}.yr^{-1}$ or 272.19 $Kg.ha^{-1}$ yr^{-1}.

Average biomass

Daily total biomass values were estimated from the sum of the products of densities and average weights of recognisable cohorts.

Using appropriate software, a polynomial function was then adjusted to these data:

$$y = 1.899992+3.01*10^{-2}x+2.63*10^{-4}x^2+1.90*10^{-6}x^3+2.70*10^{-9}x^4$$

Where "y" corresponds to the biomass values and "x" corresponds to the time passed from the beginning of sampling. The average biomass was calculated dividing the integral of this function within the interval by 407, and the obtained value was 5.409$g.m^{-2}$ (54 $kg.ha^{-1}$). The $P/\overline{B}$ ratio was then estimated at 5.03.

2nd and 3rd sampling programs

In 1992-93 a total of 337 crayfish were captured, with an average POCL of 3.19 cm, an average weight of 17.18 g and average sex ratio of 0.34. Values of the condition factor for males and females were not separated due to scarcity of data. Minimum average condition values were recorded in September/October 1992 (0.42) and

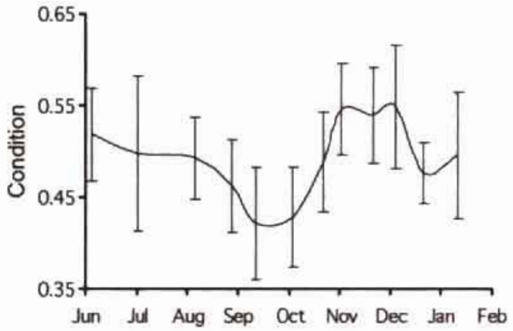

Fig. 3. Fulton's condition factor for crayfish (*Procambarus clarkii*) in the Lower Mondego river valley, Portugal, during the years of 1992/93. Crayfish of both sexes pooled together. Standard deviations are presented. N= 337.

maximum average values were recorded at the end of November/December 1992 (0.55) (Fig. 3). Average condition for all crayfish was 0.49. Size (POCL) was not significantly correlated with condition (r = 0.1, P>0.05).

During 1993-94, 2,149 crayfish were captured, with an average POCL of 2.94 cm an average weight of 15.39 g and average sex ratio of 0.47. Average POCL, sex ratio, and the proportion of Form I males (sexually active) was not constant. For this reasons data were divided into four groups: all males, females, Form I males, and Form II males. There were statistically significant differences in the average condition of these groups (ANOVA, P<0.01). Form I males had the highest average condition factor (0.595) followed by all males (0.550), females (0.529) and Form II males (0.519). Average condition factor for all crayfish captured was 0.537.

Without pooling the data by date, correlations of POCL vs. Condition were low, but statistically significant (P<0.05) for: all crayfish (r = -0.098, N = 2,149), females (r = 0.17, N = 1,450), Form I males (r = -0.18, N = 287), and Form II males (r = -0.29,

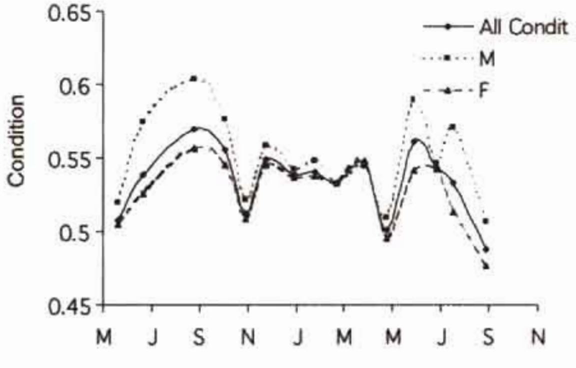

Fig. 4. Fulton's condition factor for crayfish (*Procambarus clarkii*) in the Lower Mondego river valley, Portugal, during the years of 1993/94. Results are presented for all crayfish (All condit, N=2149), females (F, N= 1450), and males (M, N=696).

N = 409); and non significant for all males (r = 0.01, N = 699). Correlations of average POCL vs. average condition values per sampling date were non-significant for any groups (P>0.05). Results for each group were: all crayfish (r = 0.19, N = 15), females (r = 0.02, N = 15), Form I males (r = 0.2, N = 14), Form II males (r = 0.43, N = 15); and all males (r = 0.28, N = 15).

In 1992-93 a decrease in condition was observed in September/October and in December/January. During 1993-94 lower average condition values were found in May 1993 and 1994, in November 1993, and September 1994 (Fig. 4). Higher average values were found in September 1993, December 1993, and June 1994.

Average sex ratio (males/females) was 0.47 and no seasonal trends were observed. Form I males were abundant (over 50% of the males) from May to October. Annual variations in the proportion of Form I males (Fig. 5) were quite similar to those of the condition factor for the overall male population. Nevertheless they were not statistically correlated (Pearson's correlation coefficient, r = 0.415, P > 0.05). There was a tendency for changes in form to start slightly before the changes in overall male condition.

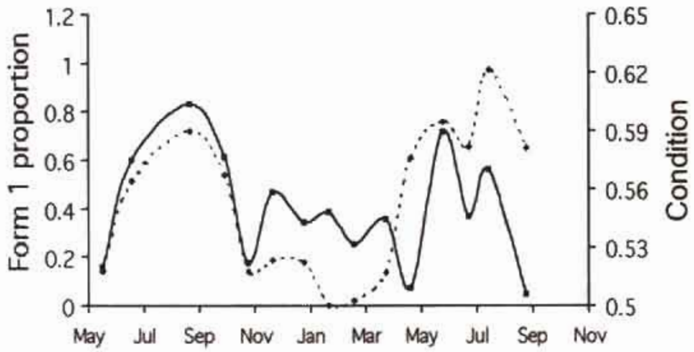

Fig. 5. Fulton's condition factor for all male crayfish (*Procambarus clarkii*) and proportion of Form I males (broken line).

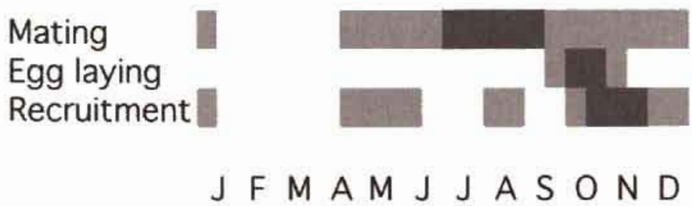

Fig. 6. Diagram representing the biological cycle of the Red swamp crayfish (*Procambarus clarkii*) in the Lower Mondego river valley, Portugal. Darker areas correspond to a more intense process. It is possible that egg laying occurs also during other periods.

Discussion

There are several peculiarities in the crayfish *P. clarkii* populations in the Lower Mondego river valley. As an example, the sex ratio differed from the values provided in the literature. In Louisiana and Kenya the number of females is slightly inferior or equal to the number of males (Table 1). Moreover, although sex ratio favourable to females have been previously reported for this species their values were usually higher than ours. Apparently there is an increase in the female proportion within the populations with increasing latitude and this may be one of the species reproductive strategies.

Table 1. Values of the sex-ratio (males/females) of crayfish *Procambarus clarkii* available in the literature.

Location	Sex ratio	Source
Kenya	2:1 in low waters. The proportion moves progressively to 1:1 as depth increases.	Oluoch, 1990
U.S.A. (Louisiana)	Average value of 1:1. Decrease on female numbers during the hottest months of the year.	Penn, 1943
U.S.A. (Louisiana)	Average value of 1:1.	Huner, 1978
Southern Spain	Approximately 1:2.	Gállego and Ocete, 1985
Central Spain	Variation during lifetime. 0.453 for smaller than 40 mm. 0.558 for individuals between 40 and 50 mm. 0.652 for individuals bigger than 50 mm.	Guerra and Niño, 1990
Portugal (Évora)	Considerable variation along the year. Proportion almost always favorable to the females.	Adão and Marques, 1993
Portugal (Elvas)	Approximately 1:1.	Correia, 1990
Portugal (Lower Mondego river valley)	Average value of 0.218.	Anastácio, 1993
Japan	Lesser than 1. Juveniles born under laboratory conditions present a value of 1:1	Sukô, 1956

It is known that in favourable conditions red swamp crayfish may have three generations per year (Huner 1981). In the lower Mondego region growth rates were relatively low compared to other areas (Table 2), which suggests that the reproductive stage is attained either after a longer period and/or at smaller sizes. According to Wenner et al. (1974) different growth rates influence the size at maturity and faster growing animals should get sexually mature at a larger size. In the present case it is considered that sexual maturity is attained at small sizes.

Thorp and Wineriter (1981) demonstrated a direct relationship between temperature and moult frequency and Sukô (1956) stated that temperatures lower than 10°C would inhibit embryonic development. Nevertheless, in the lower Mondego River region, although temperatures in early winter were lower than this limit, some newly released individuals were still found. This suggests that the population studied may have developed increased resistance to low temperatures, allowing embryonic development to occur at lower temperatures. An alternative explanation could be that a proportion of the youngest animals stopped growing, maintaining a small size for a longer period than normally observed.

P/B ratios ranging from 0.87 to 1.51 were found by other authors for P. clarkii (Momot and Romaire 1981). Nevertheless, most of the literature on the ecology of P. clarkii concerns artificial environments in Louisiana, and under natural conditions $P/\bar{B}$ ratios might differ. Production and average biomass estimated for the Mondego region might have been biased due to insufficient data on adult population density on the 1st sampling program. Assuming that the density of the adult population was under-estimated, then the real $P/\bar{B}$ ratio may be lower than 5.032.

Romaire et al. (1977) alerted to the dangers of determining regression coefficients (in size/weight regressions) for *P. clarkii* in a single sampling occasion. Fulton's condition factor is a type of a size-weight relationship and it is also variable throughout the year. Although Huner et al. (1985) obtained a linear relation for the proportion cephalothorax length / abdominal muscle weight in *P. clarkii*, Lathi's (1988) findings for male *A. astacus* were different. Relative muscle weight was length dependent. Moreover, size-weight relationships for crayfish of the genus Cherax (Lake and Sokol 1986) and also for *P. clarkii* are known to be size-dependent. In our study, there was a slight tendency for crayfish condition to depend on POCL, but seasonal variations in average POCL were not significantly correlated with average crayfish condition.

The fluctuations of the condition factor in 1992-93 were not exactly the same as those of 1993-94. Crayfish condition from late June 1992 until the end of January 1993 was not very good. Although no division into groups was performed, the reason for the inclusion of the 1992-93 data in the paper was the parallel found in the seasonal patterns for all the groups in 1993-94. The differences observed between the two sampling programs may be explained by normal environmental variations.

Fernandes et al. (1994), in a biochemical composition study carried out in 1992-93 in the lower Mondego River valley crayfish suggested that accumulated energy was used in preparation for reproduction. Data obtained in the present study during the same years (1992-93), reveals optimal condition at the same periods. It might be interesting to consider that a simple approach such as the use of a condition factor

Table 2. Growth rates of crayfish *Procambarus clarkii* found in the literature.

Author		Growth (mm/week)			Kind of research
		Body measurements			
		TL	CEF	POCL	
Lutz and Wolters, 1989	minimum	2.1	1.1	0.915	Laboratory work on character inheritance.
	maximum	7	3.68	3.05	
Craig, 1985 quoted by Lutz and Wolters, 1989		3.6	1.89	1.57	Experimental tanks with a food supply of rice.
Clark et al, 1974 quoted by Lutz and Wolters, 1989		2.8	1.74	1.21	Experimental tanks.
Huner, 1978	minimum	2.5	1.32	1.09	Monitoring aquaculture ponds (Louisiana)
	maximum	5	2.63	2.17	
Goyert and Avault, 1979	minimum	1.8	0.95	1.610.78	Experimental study to determine effect of recipient size on body growth.
	maximum	3.7	1.94	1.61	
Romaire et al, 1979	minimum	1.18	0.62	0.51	Study made on experimental tanks with crayfish from stunted populations.
	maximum	1.98	1.04	0.86	
Sommer, 1984		1.807	0.952	0.787	Juvenile growth rates on Spring and Winter (California)
Correia, 1990	minimum	0.75	0.395	0.33	Study on wild populations on Elvas region (Portugal).
	maximum	2.75	1.45	1.19	
Anastácio, 1993		1.16	0.61	0.5	Study on wild populations on the lower Mondego river valley region (Portugal).
Day and Avault, 1986	minimum (rice)	1.89	0.99	0.82	
	maximum (rice)	7.84	4.13	3.41	Study made on aquacultural ponds in order to compare the effects of different types of forage upon growth.
	minimum	0	0	0	
	maximum	12.18	6.41	5.3	

• TL – Total Lenght. CEF – Cephalotorax lenght with rostrum; POCL - Post Orbital Carapace Lenght.

may provide reliable information on the internal condition of crayfish. Moreover, our data corroborate the idea that there is a relation between condition and reproduction especially in what regards the male population. In the lower Mondego River region mating takes place from May to August, and egg-laying happens mainly in September-October. Minor recruitment periods are found in May and August. Most eggs reach the final stages of development between the end of July and the beginning of September. It seems natural that stored energy might be used for reproductive activity in males and for the growth of ovaries in females.

The division of the 1993-94 data into four groups revealed significant differences in the average condition factor. Form II and Form I males have, respectively, the lowest and the highest average condition factor. However, there was a similar seasonal pattern of variation for females, all males, reproductive males (Form I) and non-reproductive males (Form II). A decline of condition was observed at the end of the reproductive season, i.e., from September to November, depending on the years. This was followed by a recovery in the average condition factor before the winter, similarly to what was observed for *Astacus astacus* (cf. Lindqvist and Lahti 1983). The general trend from December to May seems to start as a gradual decrease in condition, ending as a steep decrease. A possible explanation is the occurrence of a massive molting of immature to reproductive forms. There is in fact some evidence to support this, since in May the proportion of Form I males suffered a tremendous increase. It seems that molting and condition are related. Nevertheless, from our findings it is not possible to predict mass molting to reproductive forms just by using the condition index.

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